OFDM for Wireless LAN (IEEE 802.11a)

ECE-299.4 Wireless Internet Technologies

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Introduction

This assignment will investigate the IEEE 802.11a standard for high speed wireless LAN at 54 Mb/s. The focus is on OFDM modulation and demodulation, training and communication through a fading multipath channel. In addition the correction of large carrier offsets between the transmitter and receiver will be investigated.

Assignment

OFDM for IEEE 802.11a Wireless LAN

System Description

The topology for the OFDM system is shown here. The digital data is generated by the *bdata* star. The 1's and 0s are mapped into a 64 point constellation. The complex QAM symbols are input to the OFDM modulator. The modulator groups 48 complex values of QAM symbols and maps them to carrier locations. The modulator then inserts 4 pilots. The modulator also inserts NULLS including one at DC. The OFDM modulator adds a guard interval prefix to each OFDM symbol obtained by performing an inverse FFT on the carriers.

Prior to outputting the OFDM symbols with guard intervals, the OFDM modulator generates the IEEE 802.11a specfied training sequence. This sequence contains 10 short training sequences, two long training sequences and a 32 sample wide guard interval for the long training sequence.

In this project you will disect and fully analyse the training sequence.

Channel Impairements

The OFDM signal passes through a baseband equivalent multi-path fading channel. The operating frequency is 5 GHz. The parameters for the fading channel model are shown here. By changing the number of reflections, their delays and power we can create various environments representing different delay spreads. We will examine the inter-play between delay spreads and the guard interval in OFDM to see when othogonality is destroyed due to intersymbol interference. We will also observe how the guard interval protects OFDM against delay spreads.

The channel also adds a fixed delay so that we can see packet detection in action at the receiver. The channel also adds noise. We will investigate the effect of noise on carrier offset estimation and

correction. Finally the channel introduces a carrier offset. This is actually due to the receiver not being able to track and lock onto the transmitter carrier. But we include it in the channel for now. The last star adds a fixed gain attenuation and phase delay. This is so that we can see how phase offsets effect the received constellation especially when channel frequency correction is not applied.

Receiver Description

The receiver assumes that the RF front end has demodulated the received signal to baseband. The receiver sampling rate is 20 MHz. In practice the receiver will operate at a higher sampling rate to perform filtering and some coarse timing recovery. The first block in the receiver is the *cxnode* star. This star replicates its input into multiple streams. One stream is processed by the *framesynch* star. This star processes the received samples and detects a new OFDM packet. This is done by correlating the input with a stored impulse response of the short training sequence. By processing the peaks in the correlation and the associated delay, the *framesynch* star is able to do the following:

- Determine whether a valid packet has arrived
- Determine the correct begining of the long training sequence
- Process the short training sequence such that packet detection and course timimg recovery are robust against noise and carrier offsets.

The *framesynch* star outputs a sample indicating when the long training sequence begins. It also acts as a valid packet indicator. The *freqoffsetcorr* star inputs the received samples and the valid packet indicator from the *framesynch* star and does the following:

- Using Moose's algorithm it processes the long training sequences to obtain an estimate of the carrier frequency offset
- It uses the estimated carrier frequency offset to correct the received OFDM samples and outputs the corrected samples to the OFDM demodulation star
- It computes the channel equalization coefficients for each carrier and provides the OFDM demodulation star with these coefficients.

The OFDM demodulation star, *fftofdm* inputs the time domain, frequency offset corrected, OFDM symbols and removes the guard interval. The star then performs a forward FFT on the OFDM samples. The resulting frequency domain samples which represent the carriers are then frequency domain equalized using the per packet equalization coefficients supplied by the *freqoffsetcorr* star.

The 48 carriers are then separated and passed to the QAM demapper. The pilots are also split off for further processing (timing drift tracking, carrier offset, doppler etc).

A Note on Sampling Rate and Bit Rate

The sampling rate for the system is is 20 MHz. The sampling rate refers to the output of the OFDM modulator and the receiver input.

Tasks

Make a new directory called OFDM and copy the contents of

~sasan/ECE299-4/OFDM

into the new directory. Use the topology:

ofdm_fading_ete

for your simulations. You will also use the topology:

ofdm_training_correlation

to investigate OFDM training and the receiver matched filters.

In the following simulations of OFDM, we use the global arguments dialog to turn certain functions on and off. Reveiw the global arguments dialog presented here.

- **Task 1. Carrier Frequency Offset Correction**

  Open the topology *ofdm-fading-ete* and bring up the global arguments dialog box. Using arg0, "Do frequency offset correction", you can turn frequency offset correction on ("1") or off ("0") at the receiver. Simulate the system with a frequency offset of 50,000 Hz. Observer the QAM constellation. Turn frerquency offset correction off. Run the simalation again and notice that the constellation has been completely destroyed. When you run a simulation, the topology creates a file called "long_analysis.dat". This data file contains the results of the long training sequence processing used to obtain the estimated carrier offset. Refer to this file to complete the table requested below.

  We wish to see the effects of noise on the estimated carrier offset. With the carrier offset set to 50,000Hz, form a table that shows the estimated frequency offset for the following levels of noise: Noise Power:

  0.0

  0.000001

  0.00001

  0.0001

  0.001

  Obtain the received QAM constellation for the following carrier frequency offsets with carrier frequency offset correction turned OFF at the receiver: Carrier Frequency Offset (Hz):

  0.0

  5.0

  10.0

  100.0

1000.0

10000.0

- **Task 2. Channel Frequency Equalization**

n this task we will turn off channel freq. equalization at the receiver and observe the QAM constellation without channel equalization. Using the global arguments dialog box, turn channel equalization off at the receiver. Run the simulation. You will observe the constellation without equalization. Turn it back on and see how equalization corrects the constellation. Use 50,000 Hz carrier frequency offset and zero noise level. Include the plots of the constellations in your report. You may want to change the parameters in the fading star and see what effect it has on the unequalized channel. For example, change the reflected ray power. Add doppler shift.

Observe the pilots. Explain why the pilots move around and are no longer on the in-phase axis when equalization is turned off. Why are there 4 clusters?

- **Task 3. Delay Spread and Guard Interval.**

Use the fading star parameters to change the delay of the reflected ray. By changing the delay to say 0.9 microsecond, the delay spread will exceed the guard interval.

Plot the received QAM constellation for delays of:

0.5 micro seconds

0.7 micro seconds

0.75 micro seconds

0.8 micro seconds

0.85 micro seconds

0.9 micro seconds

Explain your results.

In the above use a noise level of 1e-5 and 50,000 Hz carrier offset.

- **Task 4. Frequency Spectrum and Time Domain Characteristics of OFDM.**

Place a probe at the real part of the transmitter OFDM signal before the fading star. Obtain the spectrum. What is the bandwidth of the OFDM signal from the plot. Note that the sampling rate is 20MHz. Using the stat probe obtain the statistics of the OFDM signal. What is the peak to average ratio? Use IIP to extract the OFDM symbols and exclude the training. Use IIP again to obtain the histogram of the OFDM symbols. Include the histogram in your report. Compare it to a normal distribution.

- **Task 5. Short Training Sequence and Correlation.**

Open the topology *ofdm-training-correlation*. In this topology, we generate multiple OFDM packets. The packets are passed through a complex correlator which correlates the samples with the short training sequence (stored in the file *short-training.dat*). The real part of the OFDM packets is plotted as are the real and imaginary parts of the correlator output. Note that this is a complex correlator. The in-phase part will contain peaks when the short training sequences are present. These high peaks are used to determine the presence of the short training sequences.

Show that the OFDM training in fact contains 10 short training sequences.

Store the OFDM signal and extract the long training sequence. Or show the exact boundries of where the long training sequences begin and end in the generated OFDM packets. You can do this using the tools menu in IIP. This allows you to place arrows on plots to show information. You can also use the extract menu item to extract a part of a plot.

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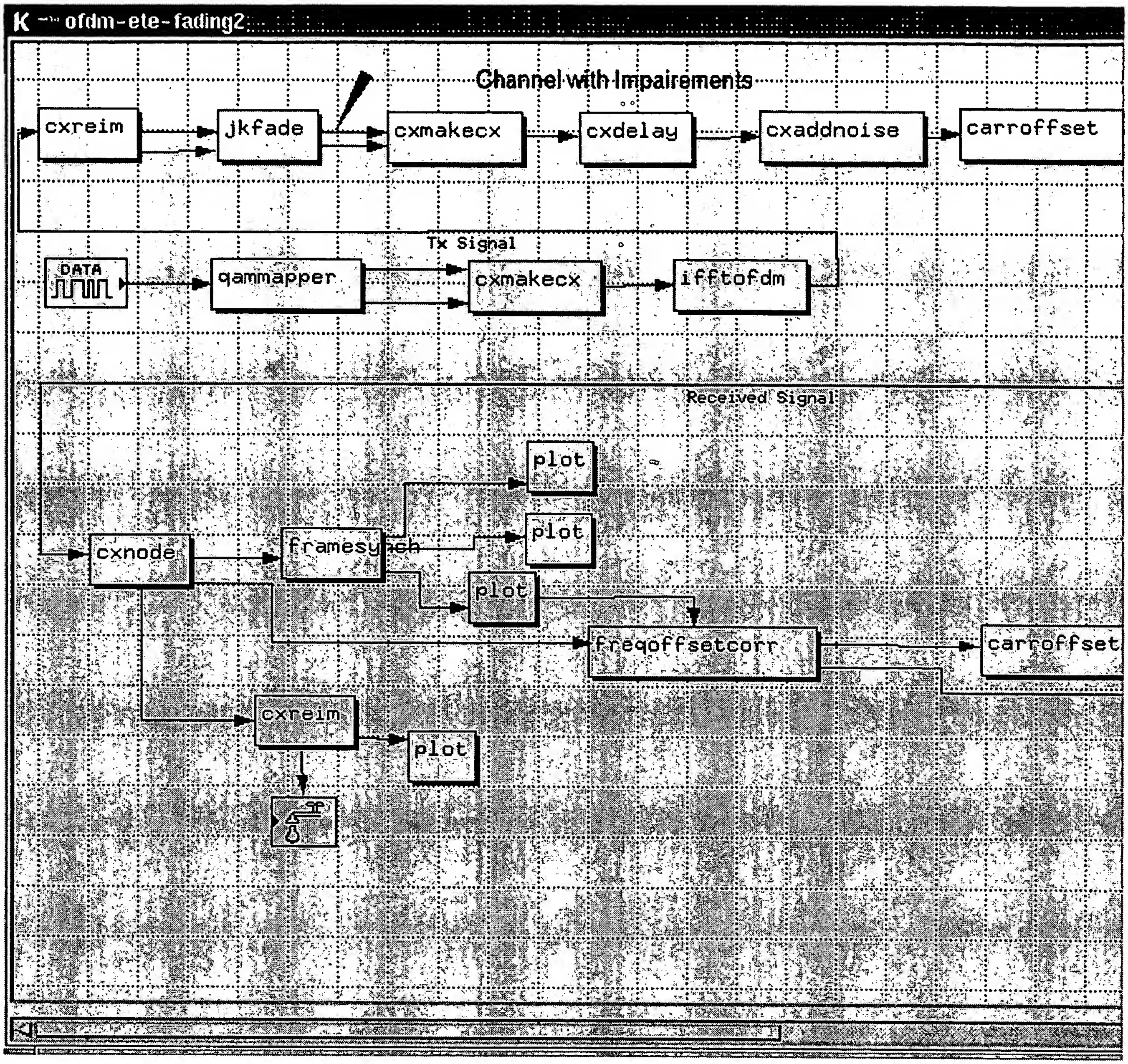

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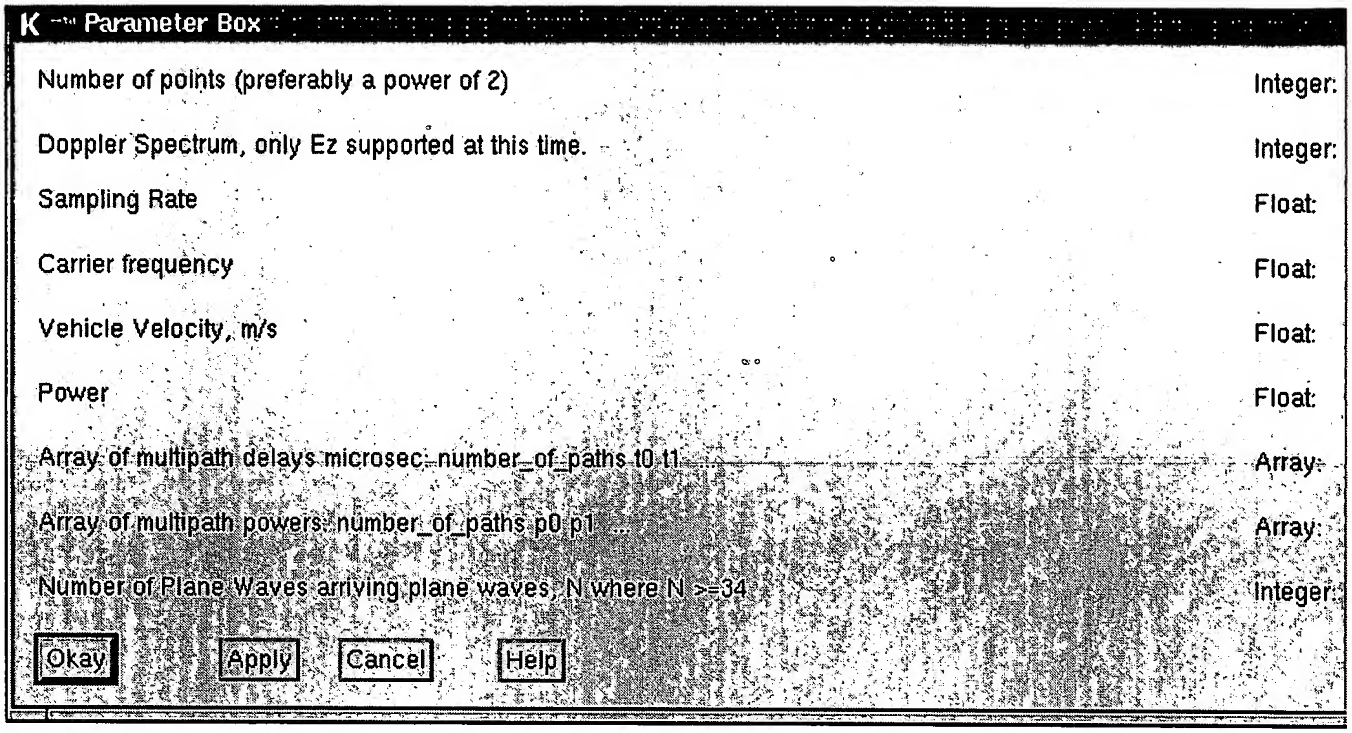

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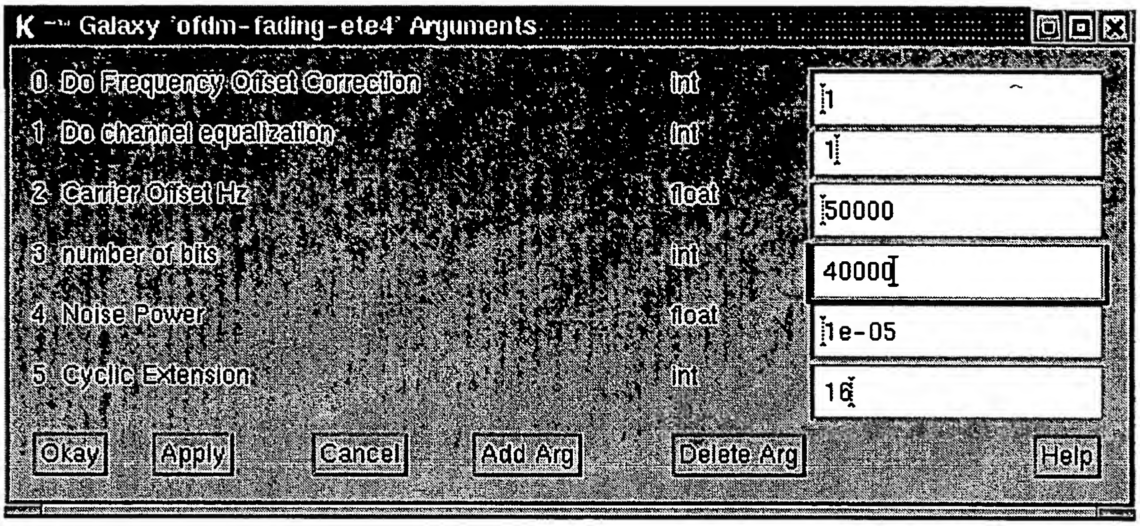

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